BIOLOGICAL EVALUATION OF THE ELONGATE HEMLOCK SCALE *FIORINIA EXTERNA* FERRIS, AND THE HEMLOCK WOOLLY ADELGID *ADELGES TSUGAE* ANNAND, INFESTATIONS AT PICATINNY ARSENAL, NEW JERSEY - 1993

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ABSTRACT

On January 12, 1993, USDA Forest Service, Forest Health Protection staff conducted a biological evaluation of insect pests causing a decline of Eastern hemlock trees Tsuga canadensis (L)Carriere at Picatinny Arsenal, Morris County, New Jersey. The primary agent found to be the cause of the decline is the elongate hemlock scale, Fiorinia externa Ferris, and to a lesser extent the hemlock woolly adelgid, Adelges tsugae Annand. The crowns of many hemlock trees are currently showing conditions of sparse, stunted and chlorotic foliage and terminal bud and branch dieback. Some tree mortality has occurred as a result of the infestation. The resource manager at Picatinny Arsenal has requested technical and financial assistance from the Forest Service to evaluate and control these insect pests. This report documents the results of our survey and management recommendations. The recommendations presented take into account treatment options, tree vigor, host composition, insect biology and population densities and the resource management objectives. Treatment is recommended only for infested open growing and ornamental trees.

INTRODUCTION

Picatinny Arsenal is located along Green Pond Mountain in Morris County, New Jersey. The Arsenal is used primarily for testing and storage of large caliber military weapons.

Much of the forest at Picatinny is made up of mixed hardwoods with oak (Quercus spp.) making up the majority of the species composition. Eastern hemlock is primarily an associated species throughout the forest at the Arsenal, but small isolated stands of hemlock do occur. Most of the hemlock is relatively young, second growth that has regenerated since the Arsenal was created.

The elongate hemlock scale Fiorinia externa Ferris (Homoptera:Diaspididae), has been a serious pest of Eastern hemlock Tsuga canadensis (L) Carr. in parts of the Northeast since its discovery in Queens, NY in 1908 (McClure, 1977). The scale was first observed at the Arsenal about four years ago. This exotic armored scale is a sap-sucking insect that feeds on the lower epidermal surface of the needles. This feeding causes needle chlorosis, premature needle drop, a reduction of tree vigor, branch dieback and in the case of heavy infestations, tree mortality.

Like the scale, hemlock woolly adelgid Adelges tsugae Annand is also an introduced pest of Eastern hemlock. A. tsugae was first reported in the eastern United States in the late 1960's and likely became established at the Arsenal within this past decade. This sap-sucking adelgid feeds on the young branches and twigs of Eastern hemlock, usually near the base of the needles. Feeding in the late winter and early spring retards or prevents the spring flush of new growth and causes existing needles to discolor, desiccate and drop from the branches. Often main limbs and the entire tree may die (McClure, 1987).

Fiorinia externa

There is usually one generation of this scale per year but in Connecticut, McClure (1977) noted a partial second generation is possible when mid-spring and fall weather conditions permit an extended period of development. The elongate scale overwinters primarily as a gravid adult female although all life stages can be found. Mature females, which can live for a year or longer, deposit eggs under a waxy cover. Egg laying occurs over an extended period and is interrupted only by cold weather. The eggs hatch in about a month and the first instar (crawlers) emerge and migrate either to new needles on the same tree or disperse to other trees, primarily by wind. Once settled, crawlers insert their mouthparts and feed for 3-4 weeks. Following this initial feeding period, the crawlers molt and mature in about 4-5 weeks. The adult males are winged and seek out females to mate. Eggs are produced in 6-8 weeks following mating. Although all stages are present throughout the growing season, crawlers tend to be most abundant during late May. This is also the time when a flush of new needles is available to colonize. The principle host of F.externa is Tsuga canadensis but more than forty other species of native and exotic conifers, including fir, spruce, and pine are also attacked (McClure and Fergione, 1977). A list of the known susceptible species is attached in Table 1.

The predominant predators of F. externa include a mirid bug, Atractotomus magnicornis nr. buenoi Knight, and the twice stabbed lady beetle, Chilocorus stigma (Say). The predominant parasites include two chalcid species, Aspidiotiphagus citrinus Craw and Aphytis nr. aonidae (Mircet). Although these small wasps have been noted to parasitize up to 96 percent of a F. externa population (McClure, 1979), successful control through inundative releases has not been previously demonstrated.

Adelges tsugae

The hemlock woolly adelgid has two wingless parthenogenetic (asexual) generations a year. Overwintering females lay eggs in March through June from which first generation adelgids will hatch. About 50 percent of the crawlers settle on the twigs near the base of the needles and develop through four nymphal stages reaching maturity by June. The newly emerged females produce and lay eggs during June and July. Crawlers of the emerging second generation adelgids settle and enter an aestivation period that lasts until October when development resumes and is completed by winter. The adult females overwinter and lay eggs which hatch in April (McClure, 1989).

The other 50 percent of the adelgids that hatch in the spring also go through four nymphal stages but into a winged, parthenogenetic generation called the sexuparae. This half of the first generation migrates to spruce to lay eggs. The hatchlings from these eggs represent the sexual part of the life cycle. However, this part of the life cycle is not well understood since studies conducted to this date have indicated that HWA is not able to complete this part of the life cycle on the Picea species that it has encountered to this point (McClure, 1989).

Females secrete a globular mass of cottony material in which the eggs are laid. These ovisacs are very conspicuous and serve as a good field character to detect infestations. Females die within the ovisac after laying their compliment of eggs.

The adelgids extract fluids from the tissues of the inner bark or phloem by inserting its stylet-like mouthparts through the outer bark at the base of needles on small twigs and branches. Damage to the host tree occurs as a result of stress induced by heavy infestations feeding on plant fluids. Additionally, it is possible that the HWA injects a toxic saliva into the tree during feeding. The saliva may disrupt plant growth hormones and modify vascular tissues in the tree simular to other adelgid species (Puritch and Petty, 1971). Consequently, trees lose vigor and become susceptible to additional and often more damaging stresses.

The control of the insect pest poses many challenges. Natural parasitoid and predator complexes are poorly known and their potential as control agents are unknown. Several natural enemies such as midges (Cecidomyiidae), flower flies (Syrphidae), and lacewings (Chrysopidae) attack A. tsugae from time to time, but their numbers are too few to be of significance in reducing adelgid densities (McClure, 1987).

METHODS

The survey consisted of visually inspecting hemlock trees at seven sites proposed for treatment. Observations regarding presence of scale and adelgid populations were recorded as were tree health characteristics including chlorotic foliage, defoliation, branch dieback and tree mortality.

At each site, three branch samples were collected and returned to the lab to determine the number of live and dead scales. A disecting microscope was used to make these counts on 100 needles from the youngest growth or the terminal ends of each branch (McClure, 1977c). An average for the three branch samples was then determined for each area surveyed. Scales were counted on a total of 300 needles to determine the average number of live and dead scales for each area surveyed. Each scale counted was probed to determined if living tissue was present. Living tissue appeared as a yellow-orange moist globular mass. Exit holes on the dorsum of the scale covering, indicative of parasite emergence, were also tallied.

Adelgid populations were sparse and no attempt was made to estimate densities in the lab. Only the presence and relative densities (light, medium or heavy) were noted during the field survey.

RESULTS

The results of the survey are summarized in Table 2. Fiorinia scale was observed at all seven sites surveyed and ranged from 17-244 (live) and 8-770 (dead) on the collected branch samples. Of the 3583 scales examined in the lab, 81 percent were determined to be dead. HWA was observed at four of the seven sites surveyed but noted to be very sparse and in low densities.

Crown conditions on hemlock trees at all seven sites were noted to be chlorotic. Branch dieback was apparent on trees in four areas, and sparse foliage and tree mortality was observed at one survey location (see Table 2).

Little evidence of parasite emergence was noted during the microscopic examination of the scales. Exit holes were observed on less than 5 percent of the scales examined from three areas. Scales from the remaining four survey areas showed no evidence of parasitism.

DISCUSSION

The health of the vast majority of hemlock trees within the Arsenal is obviously deteriorating. To date, spotty mortality is present and many of the heavily infested trees exhibit dead branches in the lower two-thirds of the crown. A number of these trees have only the upper one third of the crown remaining alive. This appearance supports McClure's vertical distribution study in which he found that F. externa densities are higher in the lower portion of the crown and decrease significantly in the upper canopy (McClure, 1977a). The relationship likely holds true for adelgid populations and associated damage as well since the wingless crawlers of this insect depend primarily on wind and would also be affected by gravity during dispersal.

Existing population densities of F. externa, and likely the A. tsugae, are sufficient to cause further impact on the health of hemlocks at Picatinny Arsenal. Studies have shown that as few as 6 scales per hundred needles can cause extensive discoloration and loss of needles in hemlocks (McClure and Fergione, 1977) and only 4 adelgids per 20 sq. mm of branch can totally inhibit the production of new growth (McClure, 1991b). Although low density estimates were observed of A. tsugae, scale densities were found to well-exceed this damage threshold.

We suspect adelgid populations will not increase significantly because of the intra-specific competition with the established scale populations and the existing poor health of the hemlocks at the Arsenal. The nutritional quantity and quality of food has been demonstrated to have a direct effect on the survival, fecundity, development rate and the establishment success of both F. externa and A. tsugae (McClure, 1979, 1991). Stressed A. tsugae populations show reduced fecundity, colonization success and an increasing proportion of the nymphs maturing to winged sexuprae which disperse from hemlocks in an unsuccessful attempt to locate a suitable Picea host.

This deterioration of the nutrition value and adequate colonization sites is probably the single most important factor involved in the collapse of both insect pests populations. Unfortunately, the factors that bring about the collapse are severe and often lethal to the hemlocks (McClure, 1991b). This observation appears to be holding true as F. externa populations are currently heavy but also appear to be declining since 81 percent of the scales examined were dead.

There are no easy remedies for the scale and adelgid problems existing at Picatinny Arsenal. We lack proven biological control options and are limited by the available technology for pesticide applications in the forest environment.

Studies by McClure,(1986, 1987) have shown that pesticide applications using ground spray equipment to spray an insecticidal oil or soap, can effectively suppress scale and adelgid populations providing the entire crown can be treated sufficiently. McClure found that on treated hemlocks, in which full coverage of the crown was not possible, both scale and adelgid populations can resurge rapidly. The surviving females of F. externa on treated trees developed more quickly and were more fecund than females from unsprayed trees. McClure also noted that surviving adelgid populations thrived on trees that were not thoroughly treated.

A second treatment option that has been used for the control of scale and adelgid populations is by means of systemic insecticides. This method involves implanting or injecting insecticides such as acephate into the xylem of the tree. These treatments offer a means of treating ornamentals, roadside and individual trees within the forest, but can also be labor intensive, expensive and impractical when treating a large number of trees. The ability of hemlocks to translocate these materials may also be impaired in trees that are already severely injured.

RECOMMENDATIONS

Forest and Roadside Hemlocks

At present there are no reasonable management alternatives available to suppress either F. externa or A. tsugae in the forest environment. Any efforts to control these pest populations on individual trees would be cost prohibitive. Treated hemlocks would quickly be recolonized through resurgence of residual populations or from dispersing populations from untreated trees.

Our recommendation is to do nothing and allow the existing scale and adelgid populations to decline naturally. This appears to be already occurring if the existing ratio of dead to live scales is any indicator.

Treatment of roadside hemlocks, growing adjacent to the forest environment, is also not recommended unless complete coverage of the crown using ground spraying equipment is possible. If systemic insecticide treatment is considered, trees must be in relatively good health to achieve adequate translocation of the insecticide. In either case, annual treatments will be necessary until populations on adjacent untreated trees collapse.

Since the hazard caused by tree mortality of roadside hemlocks is of concern, we suggest that potential hazard trees be appropriately pruned and/or removed once tree mortality appears imminent.

Ornamental Hemlocks

Ornamental hemlocks and other species susceptible to F. externa (see Table 1) should be inspected for the presence of scale and adelgid infestations. Infested trees supporting populations of F. externa greater than 6 scales per 100 needles or 4 adelgids per 20 sq. mm branch sample should be treated with an appropriate insecticide.

We recommend the use of either an insecticidal soap or horticultural oil registered for the control of these pests. Treatments should be applied in a single application prior to bud break. Should you need to treat after bud break, a "summer" or verdant oil can also provide sufficient control, however later treatments may have a more negative impact on non-target insects including scale predators and parasites. Treatments using a 1 to 50 dilution of the petroleum or insecticidal soap is the standard rate, but follow the label directions for the specific product used. For smaller trees, a backpack sprayer would be suitable for this kind of treatment. Larger trees may require the use of a hydraulic sprayer capable of reaching the entire crown. The mode of action of these insecticides is by suffication, and it is necessary to sufficiently cover the foliage, without excessive runoff. Numerous other pesticides are registered for these types of treatments but the recommended insecticides are effective and less toxic.

Fertilization of infested trees is not recommended. Previous efforts to improve the vigor of infested hemlocks by fertilizing have back-fired by increasing the nutrient levels for the sap-sucking adelgid and scale populations. Consequently, fertilizer only enhances these insects performance in both development and fecundity (McClure, 1992).

Until the scale and adelgid problem has been resolved, all of your susceptible ornamentals should be inspected annually and re-treated if necessary. Future plantings of ornamental trees should favor non-susceptible or resistant tree species.

Table 1.--Hosts of Hemlock Scales 1/

Species 2/	Common name
Abies	**FIR**
alba Mill.	Silver
amabilis Forbes	Cascade
balsamae Mill.	Balsam
cephalonica Loud.	Greek
concolor Lindl. and Gord.	White
fargesii Franchet	Farges
holophylla Maxim.	Manchurian
homolepis Sieb. and Zucc.	Nikko
veitchii Lindl.	Veitch
Cedrus	**CEDAR**
atlantica Manetti (9)	Atlas
deodara Loud. (2)	Deodara
libani Lawson (2)	Lebanon
Picea	**SPRUCE**
abies Karst. (20)	Norway
asperata Masters (1)	Dragon
glauca Voss	White
glehni Masters	Saghalin
heterolepis Rhed. and Wil.	Red twig dragon
jezoensis Carr. (1)	Yezo
koyamai Shirasawa	Koyama
mariana Britt.	Black
omorika Pancic (2)	Serbian
orientalis Carr. (2)	Oriental
pungens Engelm. (10)	Colorado
smithiana Boiss.	Himalayan

Species	Common name
Pinus	**PINE**
aristata Engelm.	Bristle cone
bungeana Zucc.	Lacebark
cembra L.	Swiss stone
densiflora Sieb. and Zucc. (3)	Japenese red
flexilis James (2)	Limber
mugo Turra (2)	Mugo
parviflora Sieb. and Zucc. (6)	Japanese white
pumila Regel	Dwarf stone
resinosa Ait.	Red
rigida Mill.	Pitch
strobus L. (5)	White
sylvestris L. (7)	Scots
Pseudotsuga	
menziesii Britt. (4)	Douglas fir
Taxus	**YEW**
baccata L. (1)	European
cuspidata Sieb. and Zucc. (1)	Japanese
Tsuga	**HEMLOCK**
canadensis Carr. (25)	Canada
caroliniana Engelm.	Carolina
diversifolia Masters	Japanese
heterophylla Sarg.	Western
sieboldii Carr.	Siebold

1/ Extracted from McClure 1986.

2/ Numbers in parentheses are the numbers of additional varieties and/or forms of the conifer species on which mature scales occurred.

Table 2.--Survey Results of *Fiorinia* Scale and Hemlock Woolly Adelgid at Picatinny Arsenal, January 12, 1992.

Location	Live Scales[1/]	Dead Scales[1/]	Parasite Evidence[2/]	HWA Present[3/]	Hemlock Stand Setting	% Hemlocks In Stand	Stand Conditon
Enclosure 200	244	271	None	Yes	Forested	70%	Chlorotic Crown
Encls 500-900	105	770	Few	No	Forested	25%	Chlorotic Crown
Enclosure 1000	51	730	Few	No	Forested	30%	Chlorotic Crown Dieback
Encls 1000-1300	64	361	None	No	Forested	30%	Chlorotic Crown Dieback
Enclosure 1300	160	553	Few	Yes	Forested	5%	Chlorotic Crown Dieback
Quarry Road	17	218	None	Yes	Forested	10%	Chlorotic Crown Sparse Foliage/ Mortality
Building 79	31	8	None	Yes	Ornamental	-	Chlorotic Crown

1/ Average number of *Fiorinia* scales per 100 needles

2/ Exit holes observed on the dorsum of the scale covering indicating parasite emergence. Few = less than 5%.

3/ Hemlock woolly adelgids present on any of the foliage observed during the survey.

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Reply To: 3460

Date: April 26, 1993

Mr. John Milio
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SMCAR-ISE-OBL, Building 302
Picatinny Arsenal, NJ 07806-5000

Dear John:

Enclosed are the results of our biological evaluation of the elongate hemlock scale and the hemlock woolly adelgid at Picatinny Arsenal. As we discussed earlier, the Forest Service will support the treatment of infested hemlock trees that are accessible by ground spraying equipment and where complete coverage of the foliage is possible. This will essentially limit the treatments to open-grown hemlock trees.

Our choice for the insecticide would be either a horticultural oil or an insecticidal soap. Both have proven effective and both are considered relatively non-toxic. Treatment timing for these materials should be prior to bud-break. If treatments cannot be completed prior to bud break, a "summer" or verdant oil is acceptable and can be used throughout much of the growing season. Keep in mind that no fertilizer should be applied to infested trees until you are sure the treatment was successful in eliminating scale and adelgid populations. Stimulating succulent vegetative growth by using nitrogen fertilizers will only enhance these pest populations, and actually accelerate the damage to the host plant.

You will not need to resubmit another FS-3400-2 Project Proposal form indicating the adjusted costs and number of trees you plan on treating, but please keep me informed as to when you plan to start as I would like to collect some pre- and post-treatment data.

Good luck!

Sincerely,

Brad Onken

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Enclosure

cc: AO
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BPO/mac